SOME EFFECTS OF SOIL INSECTICIDES

ON THE SOIL AND CROP PLANTS

by

GEORGE B. WAGNER

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INTRODUCTION

The control of subterranean insects has long been recognized as one of the most difficult problems confronting the economic entomologist. All recognize the importance of an ecological study of an organism's habitat in the development of control measures. Although many insecticides have been recommended throughout the literature, little or no mention has been made of the effect of the chemicals upon the soil environment.

Treating the soil with chemicals renders the dynamic nature of the soil more complex and in many cases has an effect on the chemical and physical properties as well as the biological activities of any soil type. Many of these compounds have an effect, either directly or indirectly, upon plants grown upon a treated soil. All references in the literature refer to effect on the insect and little or no attention is given to effect of the insecticide on the soil. The problem of soil insecticides therefore calls for cooperation between the edaphologist, agronomist, soil bacteriologist, chemist, plant physiologist, and economic entomologist.

The work presented in this paper is that accomplished during the past year on the effects of a number of soil

insecticides upon the soil, soil biology, and crop plants.

It is planned to discard any chemical which proves decidedly detrimental to the soil or crop in any way. The ones having the least deleterious effect will later be tested as to their toxicity to insects.

Acknowledgment is hereby given to my instructors, Professor J. W. McColloch of the Department of Entomology and Dr. F. L. Daley of the Soils Department for their many suggestions and kindly criticisms. These two men were never too busy to give their attention to any detail of the work. Acknowledgment is given to the Agronomy Department for the use of their Soils laboratory and equipment. Professor Gainey of the Bacteriology Department allowed the unrestricted use of his laboratory and equipment, and gave much helpful advice on the soil microbiology phase of the work. Dr. E. C. Miller of the Botany Department kindly allowed the writer to use his extensive bibliography. Mr. C. A. Gunns, technician of the Zoology Department, helped by allowing the writer the use of his dark room for the developing of photographs.

REVIEW OF LITERATURE

There is no place in entomological literature where a complete bibliography on soil insecticides can be found. While no claim is made for completeness the writer feels that the major topics have been taken up and discussed in this review of literature. The contributions are grouped under the chemical which is discussed or recommended.

Arsenicals

Headden (1910) ascribed the death of a number of apple trees in Colorado orchards to arsenical poisoning. Upon finding soluble arsenic in lesions around the collar which were similar to the disease "collar rot", he concluded that the lesions were due to the presence of soluble arsenic and that spraying with arsenicals was a dangerous practice. Ball, Titus and Graves (1910), working in Utah and Colorado, point out that Gano and Ben Davis are most susceptible to these arsenical lesions about the collar. These varieties are also especially susceptible to a fungous disease known as "collar rot". They show that the orchards in which trees are dying (especially Jonathan) were underlaid with an arsenical bearing marl, and that

trees were affected worse during seasons of a high water table. Their closing statement is, "In such cases alkali itself is sufficient to cause the death of trees."

Zhitkov (1912) shows Paris green to be toxic to pine seedlings when used in concentration greater than 3.5 drams to 2.7 gallons of water.

Brenchley (1914) states, "It is incorrect to say that arsenic is always present in, or is essential to plant tissue." She shows arsenic acid to be harmful to maize plants if present in quantities of one to 20,000 parts. Concentrations of arsenious acid, one to 10,000 and upward, completely stopped growth of peas and barley. Depressed growth was noticed in concentrations of one to 10,000 parts. Sodium arsenite in concentrations of one to 250,000,000 parts depressed growth of barley and peas. Concentration of one to 2,500,000 parts usually gave a slight depression and would sometimes strongly check development. Brenchley states, "At the Rothamsted Station no stimulation has yet been obtained with any plant with the possible exception of the white lupine. Barley grown in very weak concentrations of As_2O_5 develops fine, healthy, green colored leaves and a stimulating effect is suggested, but dry weights do not uphold this theory."

Graves (1916) found lead arsenate to have a stimulating effect on nitrification. Sodium arsenate, arsenic trioxide and zinc arsenite in the order named also showed a stimulating action. Paris green is very toxic when the concentration reaches 120 ppm., the toxicity being due to copper and not to arsenic. Sodium arsenite was toxic in concentrations of 40 ppm., and nitrification was stopped at 240 ppm. Lead arsenate was not toxic in concentrations of 400 ppm. The stimulation is greatest when the water soluble arsenic content is about 10 ppm. He says, "The main part of the stimulation noted in the soil is undoubtably due to the arsenic inhibiting injurious species."

Illingsworth (1917) states, "Humus has a marked affinity for arsenic which has a deflocculating effect on the soil, making it more retentive of moisture. He expresses a hope that arsenicals will prove efficient weed destroyers and grub killers.

Illingsworth (1919) recommends the addition of 10 pounds of white arsenic to 500 pounds of meat work manure, which is then applied to one acre of land. If applied at the rate of 20 pounds per acre, grubs did not appear at all.

Illingsworth (1921) proves 80 pounds of white arsenic to be efficient in the control of <u>Isodon puncticollis</u> Macl. in gardens.

Miller (1924) recommends calcium arsenate and sulphur, one pound each to four pounds of hydrated lime for the control of the Mexican bean beetle, *Epilachna corrupta*. This mixture should be applied at the rate of 15 pounds per acre, four applications being made.

Leach (1926) suggests the use of lead arsenate at the rate of 1500 pounds per acre in nurseries to control *Popillia japonica*. He states, however, that the ultimate effect is not as yet known and advises against the treatment of large areas.

Leach and Lipp (1927) recommend acid lead arsenate at the rate of three and one-half pounds per 100 square feet against *Popillia japonica*. This should be spread evenly over the surface of the soil and worked to a depth of four inches. They show that this treatment kills grubs, stimulates growth of grass and reduces germination of weed seed.

Sanders and Fracker (1916) working in Wisconsin on Lachnosterna grubs, show that 22.2 per cent of the larvae are killed by dipping the roots into sodium arsenite solution at transplanting time. No injury to the plants was noticed.

Morris and Swingle (1927) show that plants differ in tolerance to arsenic. Beans and cucumbers are very susceptible while cereals and grasses are more resistant.

Arsenic trioxide decreases transpiration of oats when in concentrations as low as one to 1,000,000 ppm. Tomatoes show a decrease in transpiration if grown in concentrations of 10 to 1,000,000 parts, and this decrease is more apparent in direct proportion to the amount of arsenic added until serious injury or death results. Arsenites are more toxic than arsenates. In sand cultures (other conditions being equal) the injury is apparent in a shorter time. They state, "The incorporation of arsenical compounds in the soil is a dangerous practice and may cause considerable injury as the concentration increases.

Carbon Disulphide

Carbon disulphide was the first chemical to be used as a soil insecticide. Marion (1877), working in France, used this material against the grape phylloxera.

Comstock, Comstock and Slingerland (1891) recommended the use of carbon disulphide at the rate of 150 pounds per acre against grubs in lawns.

Molet (1914) applied carbon disulphide to the soil at rates varying from 176 to 3344 pounds. He worked with the effect on insects, nematodes, white grubs, and mole crickets; on plants, tomatoes, carnations and beets. He advises a delay of 15 to 20 days after treating the soil

before sowing; also, the addition of nitrate of soda at planting time. This chemical should not come into contact with the roots. E. Holm is cited by him as saying, "The introduction of carbon disulphide into cultivated soil has the effect of either completely or temporarily arresting vegetation and diminishing production of vegetable matter.

Cook (1914) and Headlee (1916) show white grubs to be controlled by injections of carbon disulphide into holes in the soil, the holes being immediately plugged up.

Fred (1916) found carbon disulphide to temporarily reduce the microorganisms. This is followed by a great increase in number of bacteria and a corresponding increase in production of by-products or soluble nitrogen is noted. From the evidence, it seems that carbon disulphide in soil produces an increase in soluble compounds of nitrogen and sulphur.

Gainey (1913) found carbon disulphide and toluol if added in quantities to check the azotobacter group, usually destroyed the organisms. He states, "There is no evidence in these experiments to show that treatment with antiseptics stimulates the nitrifying organism, and there is little evidence to indicate a stimulating effect upon the ammonifying or nitrogen fixing organisms."

Jarvis (1922) working with the cane beetle proved that injections of one-eighth ounce would kill eggs at a distance varying from four and one-half to eight inches.

O'Kane (1922) states, "lateral diffusion seems to take place with equal rapidity and effectiveness in both fine and coarse soils." He shows that injection of the material between the two-inch and four-inch level to be the most effective.

Melander (1924) using an aspirator to pull gas through the soil found gas passed through it almost as fast as if there had been no soil present.

Emulsions

Brodaz (1914) used a carbon disulphide emulsion consisting of equal parts of carbon disulphide and vegetable oil of the lowest quality. This, when poured in the required amount of slightly alkaline water, successfully controlled eelworms of coffee.

Headlee (1924) found one-half to one fluid ounce of carbon disulphide emulsion to one to two quarts of water controlled wireworms, but also seriously checked cabbage. This amount of the diluted emulsion was added to each square foot, and watered with three gallons of water.

Fleming (1925) states, "Carbon disulphide, emulsified with water and so interspersed throughout the soil, appears to be the compound best adapted, of those studied, for freeing the soil about the roots of nursery stock of the possible infestation by the Japanese beetle."

Johnson (1927), Leach and Lipp (1927), Leach, Lipp and Fleming (1927) showed that grubs in lawns and golf greens were controlled by the use of carbon disulphide emulsions. Three formulae are given for the preparation of the emulsions.

Sanders and Fracker (1916) showed that kerosene emulsion was useless when used at ordinary strengths against Lachnosterna grubs in Wisconsin.

Naphthaline

Board of Agriculture, London (1916) states, "Naphthaline used at the rate of two ounces per square yard and well worked into the soil, followed by a thorough watering has been successfully used against grubs.

Theobold (1927) showed that cockchafer larva were not affected by applications as high as 600 pounds per acre.

Marie (1927) recommends 30 grams of naphthaline per square meter against Melolontha melolontha. This should

be broadcasted at the beginning of oviposition period and again two weeks later.

Corrosive sublimate

Britton (1920) found corrosive sublimate to control onion maggots, but was not effective against fully grown cabbage maggots (Cortophila brassicae).

Paradichlorobenzene

Essig (1916) used paradichlorobenzene against peach tree borer, wooly apple aphis, pear root aphis, grape phylloxera, wireworms, garden centipede and raspberry crown borer. He recommends that one ounce of the material be placed in rings around the trunks of mature trees, and in the case of seedlings 10 ounces per linear yard. Getting the chemical in contact with the roots or trunk should be avoided. Avoid applying in the early spring or winter, and do not wet the soil soon after application.

Golovyanko (1927) found the larva of Polyphylla fullo L. to be controlled by placing one-fourth ounce of paradichlorobenzene in holes three and one-half to four inches deep. These holes should be in rows 10.5 inches from the freshly set grapes and separated from the next in line of holes by a distance of 21 inches.

Cyanide

Hyslop (1914) placed sodium cyanide in hills of potatoes at the rate of 300 pounds per acre to control wireworms. This proved efficient, but he has evidence that it checks beneficial nitrifying bacteria.

French (1916) found 92 to 98 per cent wireworm larva to be killed by an application of sodium cyanide at the rate of one-half to five ounces to ten cubic feet placed at a depth of eight inches. By delaying date of planting two weeks germination of bean seeds was not affected.

Peterson (1918) states, "Wireworms in the soil can be controlled by heavy applications of sodium cyanide, but amounts sufficient to control pests render treatment too expensive for field use.

DeOng (1917) established a definite ratio between minimum dosage toxic to insects and maximum dosage toxic to germinating seeds and plants. He shows .0156 grams sodium cyanide toxic to flies while .125 grams sodium cyanide per liter proved toxic to beetles. His closing statement is, "Dosages toxic to flies and phylloxera would be safe for all the plants worked with, while those toxic to beetles would be extremely dangerous if not fatal to plants."

Melander (1924) estimated it would take 700 pounds of calcium cyanide to fill the pore space in the aspirator which he worked. He recommends the use of a bait and then application of calcium cyanide to the soil.

Headlee (1924) found applications of one ounce of calcium cyanide per square foot controlled wireworms but killed cabbages. This application indicated that a killing zone was established three inches laterally and twelve inches vertically from the point of application. Applications at the same rate at time of plowing failed to give control, but killed beets planted a few days later.

Britton (1926) found grubs of Anomala orientalis to be controlled by an application of calcium cyanide or sodium cyanide at the rate of four ounces per square yard. This when followed by a thorough watering also killed the grass.

Miles (1926) and others recommend planting of trap rows to concentrate the soil forms and after a given length of time drill cyanogas into the rows at the rate of six pounds per 1,000 linear feet of row.

Pomeroy (1927) used 160 pounds of sodium cyanide dissolved in 1200 gallons of water against white ants on the Gold Coast.

Watson (1927) found mole crickets to be effectively controlled by calcium cyanide applied at the rate of 1200

pounds per acre scattered ahead of the furrow wheel so the plow would cover it.

Borax

Luden (1915) recommends the use of a one per cent solution of borax against wireworms of strawberries.

Bishopp (1927) suggests one pound of borax be sprinkled over each 16 cubic feet of manure and thoroughly watered in for the control of the stable fly. He states, "This will not injure the fertilizing value if used in the quantities indicated, and not over fifteen tons of the treated manure is applied per acre.

Skinner and Allison (1923) found borax at the rate of five pounds per acre drilled in the row not always injurious; 10 pounds distinctly so, and 20 pounds to cause severe injury. A five-pound application decreased green weight of cotton plants 5.7 per cent; 10 pounds decreased weight 12 per cent, and 20 pounds decreased weight 39 per cent.

Conner (1918) and Blair and Brown (1921) showed 50 pounds of borax per acre slightly affected yields of potatoes. One hundred pound applications cut yield of potatoes in half and 200 and 400 pound applications decreased the yields to nothing. Five pounds per acre

affect the germination of corn. Applications of 50 pounds per acre cut yields of corn from 19.2 to 3.41; applications of 100 pounds per acre cut the yield to .62. The rainfall for the above season was above normal.

Brenchley (1914) found concentrations of 50 milligrams per kilogram in pot work to be extremely detrimental.

Sodium Fluosilicate

Osborn (1926) used sodium fluosilicate at the rate of 10 pounds per acre. Three applications were made at intervals of four days, making a total of 30 pounds per acre a year.

Marcovitch (1924) used sodium fluosilicate diluted one part to nine parts hydrated lime and 15 to 25 pounds of the mixture per acre. Three to six applications per acre controlled the Mexican bean beetle.

General

Dingler (1922) experimented with explosives in the soil, both alone and with poison gases as a means of soil insect control. He concluded that, to be most beneficial, the action would have to be horizontal, and that blasting was unsatisfactory.

Smith (1893) states, "Nitrate of soda and Kainit are said to have been used effectively against wireworms, cabbage maggot, corn webworm and peach aphis. However, he recommends intelligent rotation of crops.

Comstock, Comstock and Slingerland (1891) proved that salt, to be effective against larvae, should be applied at the rate of eight tons per acre. Kainit applied at the rate of four to nine tons per acre gave the same results.

Dumas (1894) recommended the use of petroleum in preserving manure and in disinfecting sewers. He thought this material to be valuable in combating insects and fungous diseases.

Molinas (1914) used potassium sulphocarbonate one part by volume to 100 parts of water. Slugs, cutworms, earthworms, white grubs, longicorn beetles and millipeds were speedily killed.

Schenk (1919) advocated the concentration of cattle on areas infested with Odontria zealandica. The grubs are killed by the trampling of the cloven hoofs.

Spencer (1919) exposed seven inch flower pots to an atmosphere containing 8.7 ounces of chloropicrin per 1,000 cubic feet for 11.5 hours at 54 degrees F. with a relative

humidity of 88. Though some millipeds one and one-half inches below the surface had gone deeper all were dead 12 hours after exposure.

Bugler (1928) found sulphur unlikely to prove of value as a soil insecticide. Sulphuric acid, sulphurous acid and sulphur dioxide are all toxic to insects. Amounts of sulphur great enough to produce these compounds in concentrations that prove toxic to insects decreased the pH value to 2.8. All vegetation was killed and some wireworms, cutworms, ants, and Lachnosterna were still alive.

Kelly and Brown (1925) showed the sodium ion to have a general deflocculating effect on the soil and upon leaching with distilled water, the soil is rendered impervious to air and moisture. Calcium, on the other hand, flocculates the soil and increases permeability. The H ion of an acid replaces, in part, the sodium on the complex silicates and partially removes the deleterious effect of the sodium. Calcium must be present to entirely remove the detrimental effects of sodium.

METHODS AND MATERIALS

The materials used in this work are the same throughout the entire experiment. The soil and chemicals used in the laboratory were similar to those used in the greenhouse

and the field. It can be readily seen however that methods would vary according to the work carried on and the purpose of such work.

For convenience in discussion, the paper will be divided into three parts: Greenhouse work, field work, and work in the soils and bacteriology laboratories.

Greenhouse Work

The soil used in the greenhouse and laboratory was a silt loam taken from the surface layer in the Entomology field near the field plots. This was put through a one-fourth inch mesh sieve and moved into the greenhouse on November 20, 1928. The soil had a moisture content of 22.24 per cent, 19.49 ppm. nitrate nitrogen, and a pH value of 5.75.

Sixteen-hundred-eighty grams of the soil, containing 22.24 per cent moisture, was mixed with the respective amounts of insecticide and put into six-inch soil pots for the greenhouse work. Figure 13 shows the arrangements of these pots. Each chemical was used at rates of 400, 1200, and 2000 pounds per acre. Four pots constituted a series for each soil insecticide; the three applications mentioned in the preceding sentence being used to grow corn, and a fourth pot with an application of 2000 pounds per acre used for miscellaneous work. Twelve pots con-

taining untreated soil were used as checks; nine to grow corn and three as checks on the miscellaneous series.

On December 3, five grains of corn were planted in each of the pots having different applications of the following chemicals: carbon tetrachloride, paradichlorobenzene, naphthaline, copper carbonate, sulphur, Paris green, white arsenic, calcium arsenate, lead arsenate, sodium arsenate, sodium arsenite, sodium chloride, sodium fluosilicate, sodium fluoride, sodium cyanide, sodium bicarbonate, calcium cyanide (both calcyanide and cyanogas), calcium fluosilicate, calcium hydroxide, copper sulphate, chloropicrin, ammonium sulphate, kerosene emulsion, carbon disulphide emulsion, toluol, tobacco dust, sodium chlorate, borax, and mercuric chloride.

The nine checks plus the above mentioned pots made a total of 108. The pots were watered daily (miscellaneous series also) according to dryness of surface. Once each week each pot was put on the scales and brought up to moisture standard. In this manner the moisture content was kept between 22 and 30 per cent. The corn was allowed to grow until it reached a height of about six inches when the soil in each pot was put through a one-fourth inch mesh sieve to remove the roots. As soon as one crop was removed, five more kernels were planted. In this manner

five crops of corn were grown. Germination and rate of growth were taken on all five crops. Due to lack of time the roots and tops of the fifth crop were not weighed.

The miscellaneous series (already described) was weighed daily and water added to bring each pot up to moisture standard to determine evaporation. This procedure was continued for a ten-day period.

Following the rate of evaporation experiment, an experiment to test the resistance of the treated soils to a penetration was started. The apparatus shown in Figure 33 was used for this purpose. Each time the weight was dropped its full distance .511 foot pounds of pressure was exerted on the central rod. This rod in turn overcomes .511 foot pounds resistance of the soil. Two determinations were made in this way.

Field Work

Field work began in June 15, 1927, by treating 27 one-thousandth-acre plots with the following insecticides:

Plot No.	Treatment	Rate of Application Pounds per acre
1	None	Check
2	Paris green	46.9
3	Paris green	375
4	Lead arsenate	141
5	Lead arsenate	1000
6	White arsenic	500
7	Calcium arsenate	1000
8	Tobacco dust	1000
9	Sulphur	1000
10	None	Check
11	Sodium fluoride	500
12	Sodium fluosilicate	500
13	Calcium fluosilicate	500
14	Crude naphthaline	312.5
15	Flake naphthaline	1000
16	Calcium cyanide (G)	312.5
17	Calcium cyanide (G)	1000
18	Sodium cyanide	162.5
19	None	Check
20	Sodium cyanide	1000
21	Hydrated lime	1000
22	Paradichlorobenzene	312.5
23	Paradichlorobenzene	1000
24	Copper carbonate	500
25	Copper carbonate	1000
26	Bone meal	1000
27	Vigero	1000

Laboratory Work

In order to determine the effect of the chemicals on nitrifying bacteria, 100-gram samples of the soil were used in the bacteriology laboratory. One-hundred grams of soil was thoroughly mixed with the required amounts of the insecticide plus five milligrams of ammonium sulphate and placed in a 500 cc. glass bottle. The moisture content was then raised to 40 per cent. These bottles were allowed

to incubate for four weeks; each bottle of soil being brought up to moisture standard once a week. A series of bottles for each chemical was treated as follows:

1. check
2. .1 gm. of respective chemical
3. .5 gm.
4. 1.0 gm.
5. 1.5 gm.

Each of the above had a check bottle which was treated in the same manner. Due to lack of time, carbon tetrachloride, mercuric chloride, sodium chloride, chloropicrin, sodium chlorate were not included in this experiment.

The rate of rise of capillary moisture was determined as follows: Ordinary slender lamp chimneys were filled with soil treated at the rate of 2000 pounds per acre. These were set in a trough of running water. This gave a check on effect of each chemical on the soil structure.

RESULTS

Greenhouse

Tables I to V show the rate of germination for the five crops, and graphs 1 to 5 show the rate of growth for these crops. A comparison of the tables show that the arsenicals retard the germination of corn. Borax,

TABLE I. RATE OF GERMINATION

Numbers show number of plants above ground each day after date of planting

Five grains planted in each pot

Chemical	Rate of application	6	7	8	9	10	11	12	13	14
		Days after Planting								
Check 1		0	5							
CS_2	400		3	5						
	1200		1	5						
	2000		4	4	5					
CCl_4	400		4	4	5					
	1200		4	5						
	2000		5							
$C_6H_4Cl_2$	400		4	5						
	1200		4	5						
	2000		3	5						
$C_{10}H_8$	400		3	4						
	1200		0	0	0	0	1	1	2	
	2000									
$CuCO_3$	400		4	5						
	1200		3	3	5					
	2000		1	2	5					
Sulphur	400		3	5						
	1200		4	5						
	2000		3	3	4	5				
Paris Green	400		1	2	2	4	5			
	1200		0	0	0	1	3	3	4	
	2000									
White Arsenic	400		2	5						
	1200		0	2	4	4	5			
	2000		0	0	2	3	4	4	5	
$Ca_3As_2O_8$	400		3	3	4	5				
	1200		0	0	3	4	5			
	2000		0	0	2	2	4	4	4	5
Check 2			4	5						
$PbHAsO_4$	400		5	5						
	1200									
	2000									
Na_2HAsO_4	400		3	5						
	1200		1	1	4	4	5			
	2000									
Na_3AsO_3	400		1	2	5					
	1200		0	0	2	2	4	4	5	
	2000									
NaCl	400		2	5						
	1200		0	0	4	4	5			
	2000		1	3	5					
Na_2SiF_6	400			5						
	1200		0	1	3	4	5			
	2000		0	1	2	3	5			
NaF	400		5							
	1200		4	4	4	5				
	2000		1	3	4	5				
Na_2CO_3	400			3	5					
	1200		3	3	5					
	2000		3	5						
Check 4			3	5						

Chemical	Rate of application	6	7	8	9	10	11	12	13
		Days after Planting							
NaCn	400		3	5					
	1200		4	5					
	2000		1	4					
$Ca(OH)_2$	400		4	5					
	1200		1	3	4				
	2000			3	5				
$CaCn_2$(G)	400		3	5					
	1200		1	5					
	2000			1	4	5			
$CaCn_2$(Cal)	400		3	5	5				
	1200		5	5	5				
	2000		5	3	5				
$CaSiF_6$	400		3	4	4	5			
	1200			2	3	4			
	2000		1	5					
$CuSO_4$	400		2	5					
	1200		1	3	4	5			
	2000		1	3	4	5			
Check 3			5						
Tobacco Dust	400		3	5					
	1200		5						
	2000		5						
Check 5		5							
CCl_3NO_2	400		5						
	1200		3	3	5				
	2000			4	5				
$NH_4(SO_4)_2$	400		3	3	3	4			
	1200		2	4	5				
	2000			4	5				
Check 6			2	5					
Kerosene Emulsion	400		1	3	5				
	1200				5				
	2000			3	3	4			
CS_2 Emulsion	400			3	5				
	1200		1	3	5				
	2000		1	3	5				
Toluol	400		2	3	5				
	1200		2	3	5				
	2000		3	3	5				
Check 7		2	5						
$NaClO_3$	400		2	4	4	5			
	1200		3	3	3	4			
	2000		1	2	3	5			
$Na_2B_4O_7$	400			1					
	1200								
	2000								
Check 8			5						
$MgCl_2$	400			1	1	2	2	3	3
	1200								
	2000								
Check 9			2	4	5				

TABLE II. GERMINATION OF CORN - SECOND CROP

Numbers Show Number of Plants Above Ground Each Day After Date of Planting

Five Grains Planted in Each Pot

Chemical	Rate of application	Days after Planting 7	8	9	10	11	12	13
Check 1		1	5					
CS_2	400	1	3	5				
	1200							
	2000		2	5				
CCl_4	400	2	4					
	1200			5				
	2000		2	4	5			
$C_5H_4Cl_2$	400		1	5				
	1200		1	3	4	5		
	2000		4	5				
$C_{10}H_6$	400		1	4	5			
	1200		1	5				
	2000	1	2	5				
$CuCO_3$	400		0	5				
	1200		1	5				
	2000			4	5			
Sulphur	400	3	4	5				
	1200		3	5				
	2000		4	5				
Paris Green	400			4	4	4	5	
	1200				1	3	3	4
	2000			1	1	3	4	
White Arsenic	400		2	5				
	1200			2	2	5		
	2000		1	1	2	3	5	
$Ca_3As_2O_8$	400	2	3	5				
	1200		1	4	4	5		
	2000		3	5				
Check 2		3	5					
$PbHAsO_4$	400		3	4				
	1200		1	4	5			
	2000		1	5				
Na_2HAsO_4	400		4	5				
	1200	1	1	4				
	2000					2	2	5
Na_3HAsO_3	400		2	5				
	1200		1	2	3	4		
	2000			2	2	3		
NaCl	400		3	5				
	1200		5					
	2000		3	5				
Na_2SiF_5	400	1	4	5				
	1200		1	2	5			
	2000							
NaF	400	2	5					
	1200		2	4	4	4	5	
	2000		1	3	4			
$NaHCO_3$	400		3	5				
	1200		4	4	5			
	2000		2	5				
Check 4		2	4	5				

Chemical	Rate of application	Days after Planting 7	8	9	10	11	12	13
NaCn	400		2	5				
	1200		1	3	5			
	2000			1	3	4		
$Ca(OH)_2$	400		1	4	5			
	1200		2	5				
	2000		1	2	5			
$CaCn_2$(G)	400		1	5				
	1200		2	5				
	2000			5				
$CaCn_2$(Cal)	400	1	2	4	5			
	1200		1	2	4	5		
	2000			2	4	5		
Check 3		3	5					
$CaSiF_6$	400			3	5			
	1200			4	5			
	2000		1	3	5			
$CuSO_4$	400		1	5				
	1200			5				
	2000			1	1	5		
Tobacco Dust	400		2	5				
	1200		1	3	4	5		
	2000		3	5				
Check 5		2	5					
CCl_3NO_2	400		4	5				
	1200		1	5				
	2000		2	5				
$(NH_4)_2SO_4$	400		3	5				
	1200		4	5				
	2000	1	2	5				
Check 6		4	5					
Kerosene Emulsion	400		1	5				
	1200		2	4	4	5		
	2000	1	4	5				
CS_2 Emulsion	400		3	5				
	1200		2	4	4	5		
	2000		1	4	5			
Toluol	400		1	4	5			
	1200	1	1	3	5			
	2000		1	3	5			
Check 7		4	5					
$NaClO_3$	400		1	4	5			
	1200		1	5				
	2000		2	5				
Check 8		1	5					
$Na_2B_4O_7$	400			2	3	4	5	
	1200							
	2000							
$HgCl_2$	400	1	4	5				
	1200		2	4	4	4	5	
	2000							
Check 9		5						

TABLE III. GERMINATION OF CORN - THIRD CROP

Numbers Show Number of Plants Above Ground Each Day After Date of Planting

Five Grains Planted in Each Pot

Chemical	Rates of application	Days after Planting 6	7	8	9	10	11	12
Check 1		2	4	4	5			
CS_2	400		1	5				
	1200		1	4	5			
	2000		2	5				
CCl_4	400	1	2	5				
	1200		1	4	5			
	2000	2	5					
$C_6H_4Cl_2$	400		1	3	5			
	1200		2	5				
	2000	2	2	5				
$C_{10}H_8$	400		4	5				
	1200		2	4	5			
	2000		3	5				
$CuCO_3$	400		5					
	1200			5				
	2000			4	5			
Sulphur	400		1	4	5			
	1200		4	4	5			
	2000		2	5				
Check 2			1	2	5			
Paris Green	400				1	2	4	5
	1200				2	3	5	
	2000		1	1	1	4		
White Arsenic	400			1	2	4	4	5
	1200				3	5		
	2000			1	2	4		
$Ca_3As_2O_8$	400		4	5				
	1200		2	2	2	4	5	
	2000				1	3	4	
$PbHAsO_4$	400		2	4	5			
	1200			2	3	5		
	2000		2	2	2	4		
Na_2HAsO_4	400		2	4	5			
	1200		3	3	5			
	2000					2	2	4
Na_3AsO_3	400		1	5				
	1200		1	1	3	5		
	2000				1	5		
NaCl	400	2	4	5				
	1200		1	4	5			
	2000		2	3	3	5		
Na_2SiF_6	400	1	2	5				
	1200			1	3			
	2000		3	4	5			
NaF	400			2	2	3		
	1200	1	1	1	3			
	2000		1	2	3			
$NaHCO_3$	400		5					
	1200	1	1	2	3	4		
	2000		4	5				
Check 4		1	4	5				

Chemical	Rate of application	Days after Planting 6	7	8	9	10	11	12
NaCN	400				1	4		
	1200			1	3	4		
	2000		4	4	5			
$Ca(OH)_2$	400			3	3	5		
	1200		1	3	4	5		
	2000		4	5				
$CaCN_2(G)$	400		2	4	4	5		
	1200		2	5				
	2000		4	5				
$CaCN_2(Cal)$	400		1	5				
	1200			4	5			
	2000			1	5			
$CaSiF_6$	400			4	5			
	1200			1	5			
	2000		1	3	5			
Check 3			4	4	5			
$CuSO_4$	400		1	4	5			
	1200			1	5			
	2000			2	5			
Check 5		3	3	5				
Tobacco Dust	400		1	4	5			
	1200			1	3	5		
	2000		2	4	5			
CCl_3NO_2	400		2	5				
	1200			1	4	5		
	2000		3	4	5			
$(NH_4)_2SO_4$	400		3	5				
	1200		4	5				
	2000		3	5				
Kerosene Emulsion	400	2	5					
	1200	1	2	3	4	5		
	2000		2	5				
Check 6			2	5				
CS_2 Emulsion	400		2	4				
	1200		5	5				
	2000		5					
Toluol	400		2	2	4	5		
	1200			1	3	4	4	5
	2000	1	4	5				
$NaClO_3$	400		1	5				
	1200	1	3	5				
	2000	1	3	4	5			
Check 7		1	3	5				
$Na_2B_4O_7$	400		3	5				
	1200		1	1	1	3	3	4
	2000				1	3	3	5
Check 8			1	4	4	5		
$HgCl_2$	400	1	3	5				
	1200	1	3	4	5			
	2000	1	2	2	4	5		
Check 6		4	5					

TABLE IV. GERMINATION OF CORN - FOURTH CROP

Numbers Show Number of Plants Above Ground Each Day After Date of Planting

Five Grains Planted in Each Pot

Chemical	Rates of application	Days after Planting 6	7	8	9	10	11	12
Check 1		4	5					
CS_2	400	3	5					
	1200	1	5					
	2000	3	5					
CCl_4	400		5					
	1200	2	4	5				
	2000	3	5					
$C_6H_4Cl_2$	400	1	5					
	1200		3	5				
	2000	1	3	5				
$C_{10}H_8$	400	2	5					
	1200	3	4					
	2000	5						
$CuCO_3$	400	2	5					
	1200		5					
	2000	2	2	4	4	5		
Sulphur	400	3	5					
	1200	3	5					
	2000	2	4	5				
Paris Green	400		2	5				
	1200		2	2	4	4	5	
	2000			1	2	3	3	4
Check 2		4	5					
White Arsenic	400			2	4	5		
	1200		2	4	5			
	2000			2	3	4	5	
$Ca_3As_2O_8$	400	1	4	5				
	1200	1	1	4	5			
	2000	1	2	3	4	4	5	
$PbHAsO_4$	400	4	5					
	1200		2	4	5			
	2000	3	5					
Na_2HAsO_4	400	1	4	5				
	1200			2	2	3		
	2000			1				
Na_3AsO_3	400		3	5				
	1200			1	2	3	3	4
	2000				2	3		
NaCl	400	1	3	5				
	1200	1	3	4	4	4	5	
	2000	1	1	2				
Na_2SiF_6	400	4	4	5				
	1200		1					
	2000				1			
NaF	400		1	2	2	2	4	
	1200		1	2				
	2000		2	3	3	4		
$ZnHCO_3$	400	2	5					
	1200			1				
	2000	1	4	5				
Check 4			2	5				

Chemical	Rates of application	Days after Planting 6	7	8	9	10	11	12
NaCn	400	1	2	4	5			
	1200		1					
	2000		4	5				
$Ca(OH)_2$	400		4	5				
	1200	2	5					
	2000	4	5					
$CaCn_2$(G)	400		5					
	1200	3	5					
	2000	5						
$CaCn_2$(Cal)	400	3	5					
	1200	1	5					
	2000	2	4	4	5			
$CaSiF_6$	400	1	5					
	1200		4	5				
	2000	1	5					
Check 3		4	5					
$CuSO_4$	400	2	5					
	1200		5					
	2000	1	2	5				
Check 5		5						
Tobacco Dust	400	1	5					
	1200	2	5					
	2000		5					
CCl_3NO_2	400	3	5					
	1200	2	5					
	2000		4	5				
$(NH_4)_2SO_4$	400	2	5					
	1200	2	5					
	2000		4	5				
Kerosene Emulsion	400	4	5					
	1200	2	4	5				
	2000	4	5					
Check 6		3	5					
CS_2 Emulsion	400		4	5				
	1200	2	5					
	2000		5					
Toluol	400	2	5					
	1200		4	5				
	2000	1	5					
$NaClO_3$	400	3	5					
	1200		4	5				
	2000		4	5				
Check 7		4	5					
$Na_2B_4O_7$	400		5					
	1200						1	
	2000							
Check 8		3	5					
$MgCl_2$	400	3	5					
	1200	1	3	5				
	2000	3	5					
Check 9		5						

TABLE V. RATE OF GERMINATION - FIFTH CROP

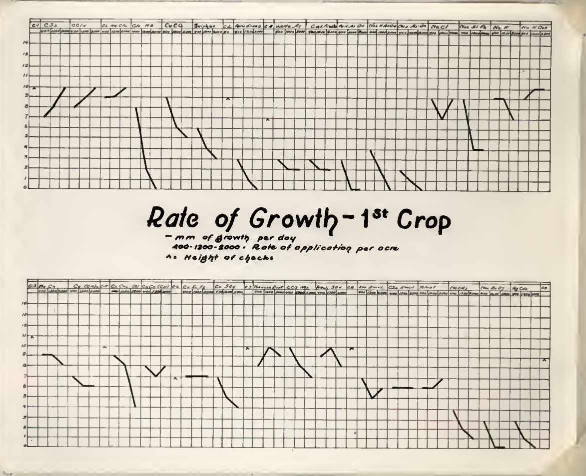
Numbers show number of plants above ground each day after date of planting

Five grains planted in each pot

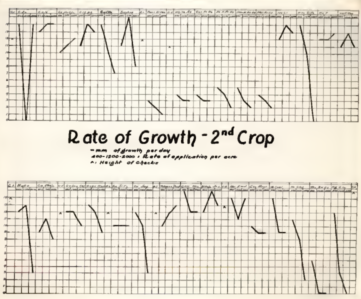
Chemical	Rate of application	Days after Planting 6	7	8	9	10
Check 1		3	5			
CS_2	400	5				
	1200	1	5			
	2000	2	5			
CCl_4	400	4	5			
	1200	3	5			
	2000	2	4			
$C_6H_4Cl_2$	400	2	5			
	1200	2	5			
	2000	4	5			
$C_{10}H_8$	400	3	5			
	1200	3	5			
	2000	4	5			
$CuCO_3$	400	4				
	1200	3	5			
	2000	2	5			
Sulphur	400	4	5			
	1200	5				
	2000	1	5			
Paris Green	400	4	5			
	1200	1	5			
	2000		1	3	4	
Check 2		5				
White arsenic	400	1	5			
	1200		4	5		
	2000	1	3	4		
$Ca_3As_2O_5$	400	4	5			
	1200	1	5			
	2000		4	5		
$PbHAsO_4$	400	3	5			
	1200	1	5			
	2000		4	5		
Na_2HAsO_4	400	5				
	1200	1	5			
	2000	3	5			
Na_3AsO_3	400	5				
	1200	1	5			
	2000		4	5		
NaCl	400	5				
	1200	3	4	5		
	2000	5				
Na_2SiF_6	400	5				
	1200		1			
	2000		1			
NaF	400	5				
	1200	1	3	5		
	2000	4	5			
$NaHCO_3$	400	5				
	1200	5				
	2000	2	5			
Check 4		4				

Chemical	Rate of application	Days after Planting 6	7	8	9	10
NaCn	400	5				
	1200	3	4	4	5	
	2000	3	5			
$Ca(OH)_2$	400	5				
	1200	5				
	2000	1	4	5		
$CaCn_2$(G)	400	5				
	1200	4	5			
	2000	5				
$CaCn_2$(Cal)	400	5				
	1200	4	5			
	2000	4	5			
$CaSiF_6$	400	5				
	1200	5				
	2000	2	5			
Check 3		5				
$CuSO_4$	400	4	5			
	1200	2	5			
	2000	5				
Check 5		5				
Tobacco Dust	400	5				
	1200	3	5			
	2000	4	5			
CCl_3NO_2	400	5				
	1200	3	5			
	2000	3	5			
$(NH_4)_2SO_4$	400	5				
	1200	5				
	2000	5				
Kerosene Emulsion	400	5				
	1200	4	5			
	2000	4	5			
Check 6		5				
CS_2 Emulsion	400	5				
	1200	4	5			
	2000	1	5			
Toluol	400	3	5			
	1200	2	5			
	2000	4	5			
$NaClO_3$	400	5				
	1200	3	5			
	2000	3	5			
Check 7		5				
$Na_2B_4O_7$	400	5				
	1200	1	3	4		
	2000	1	2	3		
Check 8		5				
$HgCl_2$	400	5				
	1200	2	5			
	2000	5				
Check 9		9				

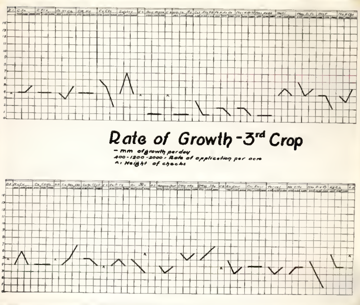
Graph 1. Plants allowed to grow for 18 days.



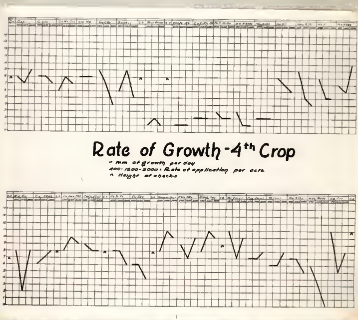
Graph 2. Plants allowed to grow for 20 days.



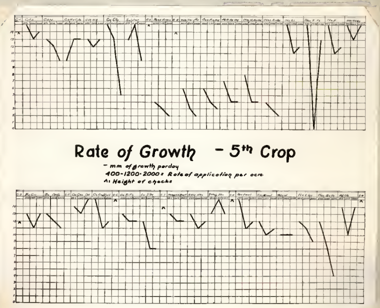
Graph 5. Plants allowed to grow for 40 days.



Graph 4. Plants allowed to grow for 18 days.



Graph 5. Plants allowed to grow for 16 days.



naphthaline, and mercuric chloride seriously retarded germination in the first planting.

Naphthaline reduced germination in the first planting, but the injurious effect seemed to disappear after the removal of the first crop (Figs. 8 and 14).

Sodium cyanide and borax were the only two that seriously retarded germination in the fifth crop, 140 days after treatment of the soil.

The arsenicals as a group reduced the rate of growth of corn. Although the corn would germinate, the root systems seemed unable to penetrate the arsenic treated soil (Figs. 22 and 25). Heavy concentrations of soluble arsenic in the soil decreased germination, and the lowest applications retarded growth of plants (Figs. 6, 8, 9, 15). Lead arsenate was the least injurious of the arsenicals used as is shown in Figure 31.

Copper compounds reduced the rate of growth in direct proportion to increase in rate of application (Fig. 17). Although the kernels germinated, the seedlings seemed unable to establish and maintain a root system. The root systems of the plants grown in the soil with the 2000 pound treatment were but little better than those grown in soil treated with lead arsenate at a similar rate as shown in Figure 25.

The sodium compounds were variable in their effect on germination and rate of growth due to the action on the complex silicates. Figures 1 to 5 show the deflocculating effect of sodium compounds on the soil as compared to calcium compounds.

The soil treated with sodium compounds becomes impervious to air and moisture, and if the surface is dry, the seedlings are unable to break through this crust and germination is reduced in this manner. Figures 7 and 16 show a reduction in the rate of growth. The roots of plants grown in soil treated with sodium compounds are large and coarse with but few root hairs (Fig. 20).

Borax greatly reduced germination in the first crop,, and reduced rate of germination throughout the entire experiment (Fig. 11). Rate of growth was reduced and this reduction was more noticeable as the moisture content of the soil decreased (Fig. 19). Figure 21 shows the roots of plants grown in soil treated with borax. The roots seemed unable to penetrate the hard soil, and the boron was toxic to young roots.

Rate of growth was checked in the sodium chlorate treatments. The plants would only make a small growth, turn yellow and die (Fig. 10).

Such substances as chloropicrin, calcium cyanide, and carbon disulphide seemed to have a harmful effect at first, but this was less noticeable with succeeding crops and in the later crops a stimulating action was suggested. This is especially true with calcium cyanide (G) and chloropicrin (Figs. 23 and 24). The cyanamid of the cyanogas and the nitrite of the chloropicrin were reduced by the nitrifying bacteria forming available nitrates which could be utilized by the plants.

Plate I shows the results of a white arsenic experiment started in 1927, and continued to date. Figure 30 shows the effect of white arsenic on the rate of growth of corn. The average of ten crops of corn, two crops of wheat and one crop of peas and beans each show white arsenic to be injurious in all cases. The average growth of both corn and wheat was reduced in direct proportion to the increase in application. While white arsenic apparently had little effect on germination of wheat, germination of corn was retarded. Beans would not germinate in the lowest application. Although the data on germination of both peas and wheat is inconclusive, average growth of peas was greatly reduced with the increasing application. Leaching one of the white arsenic treated pots with 2000 cc. of distilled water failed to remove the harmful effect.

PLATE I

FIG 1

-Shows average growth of corn in inches

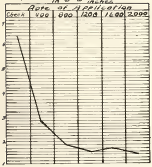


FIG 2

-Shows average growth of Wheat in inches

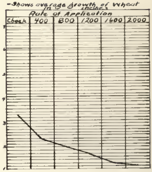


FIG 3

Average Rate of Germination of Bean

Days After Planting	Rate of Application per Acre					
	Check	400	800	1200	1600	2000
5	0	0	0	0	0	0
6	1	0	0	0	0	0
7	2	0	0	0	0	0
8	3	0	0	0	0	0

FIG 4

Average Rate of Germination of Corn

Days After Planting	Rate of Application per Acre					
	Check	400	800	1200	1600	2000
5	5	4	1	1	1	0
6	5	5	5	2	3	2
7	5	5	5	4	4	4
8	5	5	5	5	5	5

FIG 5

Average Rate of Germination of Wheat

Days After Planting	Rate of Application per Acre					
	Check	400	800	1200	1600	2000
4	1	6	0	2	5	4
5	6	7	5	3	7	6
6	6	7	5	3	7	6
7	6	7	5	3	7	6.

Evaporation experiments conducted in the greenhouse were inconclusive due to the excessive cracking in the soils treated with sodium compounds. Large cracks reaching nearly to the bottom of the pots exposed much more soil surface to the air. Water added to these pots would not be taken up by the soil, but would merely run down the cracks and out the hole in the bottom of the pots. Due to this fact no appreciable differences were obtained.

Table VI shows the resistance of treated soil to penetration as measured by the instrument shown in Figure 33. In general the deflocculating action of the sodium ion on soil treated with sodium compounds is shown by the hard, puddled appearance, and such soil is more impervious to air and moisture. This is demonstrated by the resistance of treated soils to penetration as shown by Table VI. Special attention should be called to sodium arsenate, sodium bicarbonate, sodium cyanide and borax.

TABLE VI RESISTANCE OF TREATED SOIL TO PENETRATION

Chemical Used	Pressure exerted in foot pounds
Check	2.044
Carbon disulphide	1.022
Carbon tetrachloride	1.533
Paradichlorobenzine	1.533
Naphthalene	1.533
Sulphur	.511
Copper carbonate	.511
Paris green	1.022
White arsenic	1.533
Calcium arsenate	1.022
Lead arsenate	1.022
Sodium arsenate	24.52
Sodium arsenite	2.55
Sodium chloride	1.022
Sodium fluosilicate	4.088
Sodium fluoride	4.599
Sodium bicarbonate	17.374
Sodium cyanide	15.797
Calcium hydroxide	.511
Calcium cyanide (G)	1.533
Calcium cyanide (cal)	1.022
Check	1.022
Calcium fluosilicate	1.022
Copper sulphate	1.022
Tobacco dust	1.533
Chloropicrin	2.044
Ammonium sulphate	1.533
Kerosene emulsion	3.066
Carbon disulphide emulsion	2.555
Toluol	2.044
Sodium chlorate	3.577
Borax	17.886
Mercuric chloride	1.533
Check	2.044

Field work

Results in the field work cover a period of two years. Plate II shows the results of the work on sorghums for 1927 (See page 20 for list of treatments). Paris green, calcium arsenate, and white arsenic reduced germination of sorghums. No plants were grown on the Paris green and calcium arsenate plots. Paradichlorobenzine and copper carbonate reduced average growth of sorghums.

Sodium cyanide, lead arsenate and flake naphthaline decreased the number of plants heading. Paradichlorobenzine, sodium fluoride, sodium fluosilicate, and calcium fluosilicate apparently accelerate the heading process, although the number of heads is reduced in the calcium fluosilicate plot.

Plate III shows the results of the corn experiment in 1927. The work on corn for 1928 is comparable to that of 1927. Figure 1 shows Paris green, lead arsenate, white arsenic, calcium arsenate, paradichlorobenzine, and sodium cyanide to reduce the germination of corn. The arsenical plots are still showing a deliterious effect on germination, this spring on oats. The calcium arsenate field plot is shown in Figure 26. The brace roots of corn grown on the arsenical treated plots are apparently unable

Plate II

Fig 1

% Germination

Plot No.	%
1	70
2	80
3	20
4	80
5	90
6	40
7	0
8	70
9	70
10	90
11	[illegible]
12	40
13	70
14	70
15	20
16	80
17	100
18	90
19	90
20	20
21	80
22	70
23	80
24	80
25	90
26	80
27	80

Fig 2

Average Growth of Sorghum for 1927

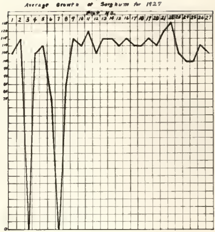


Fig 3

Heading of Sorghum

Plot No.	No. Plants Headed																		
	August									September									
	23	24	25	26	27	28	29	30	31	1	2	3	4	5	6	7	8	9	10
1									2	2	3	3	4	4	4	4	4	6	7
2								1	2	2	2	4							
3																			
4							1	1	2	2	2	3	3	3	4				
5													1						
6																			
7																			
8							2	4	4	5	6	7	7	7	7	7	7	7	8
9					1	1	1	3	5	5	6	6	6	7	8	8	8	8	9
10						1	1	4	6	6	6	6	6	8	8	8	8	8	9
11				1	2	3	4	6	8										
12	1	1	2	2	3	3	3	6	8										
13		2	2	2	4	5													
14				2	3	3	3	5	5	5	6								
15							1	2											
16							1	1	3	5	6								
17													1	1	2	2	7		
18		1	1	2	3	4	4	5	7	7	8								
19	1	2	3	4	5	6	6	7	7	8	9								
20										1	1	1	2	2	2	2	3		
21					1	4	5	5	6	8									
22						1	1	3	3	5	6	7							
23	1	2	2	2	2	3	4	7											
24	1	1	1	1	1	1	1	1	2	5	6	7							
25						2	2	4	5	5	5	5	5	5	5	5	5	5	6
26	2	3	4	5	5	6	6	8	9										
27			1	1	2	3	3	3	4	5	5	6							

Plate III

Fig 1

Germination

Plot No.	%
1	100
2	90
3	60
4	80
5	100
6	80
7	60
8	90
9	100
10	100
11	90
12	90
13	100
14	90
15	80
16	90
17	100
18	90
19	100
20	20
21	100
22	90
23	40
24	100
25	100
26	100
27	100

Fig 2

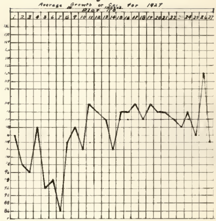


Fig 3
Tasseling of Corn
1927

Tasseling Record.

Plot No.	Aug. 11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Sept. 1	2	3	4	5	6
1	1	4	5	3	6	8																					
2		3	5	5	5	6	6	7																			
3		2	3	3	3	4	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7
4		1	2	3	7																						
5	1	3	3	3	3	4	4	6																			
6	1	4	4	6	6	7	7	8	9																		
7			2	2	2	2	2	2	2	5	[illegible]	3	3	3	3	3	3	3	[illegible]	3	3	3	3	3	3	3	4
8		6	6	7	7	7	7	8																			
9		2	5	6	9																						
10	2	6	6	6	[illegible]	8	8	8	8	8																	
11		4	6	7	7	9	9	9	10																		
12	1	3	4	5	5	8	10																				
13		2	8																								
14																											
15	1	6	7	7	8	9																					
16			2	7	7	8																					
17		3	5	6	6	7																					
18		1	2	2	3	5	5	5	5	6	6	7															
19		2	3	6	8	10																					
20		1	2	3	4	4	4	5																			
21		3	5	6	8	8	8	8	9																		
22			5	7	8	8	9																				
23		1	2	5	6																						
24		2	5	5	7	9																					
25		1	3	3	5	5	7	8																			
26	2	5	6	7	9																						
27		1	2	3	3	6	6																				

to penetrate the soil and the plants showed a tendency to lodge badly.

Figures 27 and 28 show that the corn on the plots treated with paradichlorobenzine and sodium cyanide, respectively, were stunted, while figure 29 shows the stimulating effect of tobacco dust.

Paris green, sodium cyanide, and calcium arsenate delayed tasseling. The corn in the naphthaline plot did not tassel (see Plate III, figure 3).

Beans usually would not germinate in the arsenic plots, or in cases where they did germinate a collar rot developed soon killing the plants. Tomatoes would not grow in the arsenic treated soil nor in the sodium cyanide plot.

The results of wheat grown in the field plots are summarized in Table VII.* Here again the arsenicals reduced the number of plants reaching maturity. Paradichlorobenzine reduced the development of wheat plants. No plants were produced on the plots treated with calcium arsenate, white arsenic and heavy application of sodium cyanide. Figure 28 shows the clump of wheat on plot 19.

A stimulating effect might be suggested by a comparison of the average height of the plants. But in most

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*Measurements given in centimeters.

TABLE VII . SUMMARY OF DATA ON WHEAT FOR 1928

Plot No.	Entire Crop: Total No. plants	Entire Crop: Total No. heads	Average of Ten Plants: No. tillers	No. heads	No. tillers not heading	Average height*	Condition of straw	Condition of roots
1	29	426	118	103	15	93.7	straight	normal
2	22	282	100	90	10	87.9	3 crooked	normal
3	19	251	139	101	38	95.5	5 crooked	5 weak
4	20	255	139	121	18	92.1	3 crooked	2 weak
5	14	251	151	125	26	91.8	6 crooked	6 weak
6	0	0	0	0	0	0.0		
7	0	0	0	0	0	0.0		
8	34	537	140	137	3	91.0	straight	1 weak
9	24	313	124	106	18	85.1	straight	4 weak
10	18	146	143	131	12	92.9	1 crooked	normal
11	23	341	150	127	23	97.8	crooked	normal
12	26	334	161	150	11	114.9	crooked	normal
13	21	318	122	100	22	97.5	crooked	normal
14	25	255	115	104	11	93.0	crooked	normal
15	24	231	118	118	0	97.1	straight	normal
16	33	377	103	100	3	88.2	straight	normal
17	26	321	99	93	6	88.5	straight	normal
18	20	162	100	83	17	90.8	straight	normal
19	23	141	107	87	20	82.9	straight	normal
20	0	0	0	0	0	0.0		
21	13	158	106	104	2	88.4	straight	normal
22	15	73	89	83	6	70.0	straight	normal
23	14	79	83	71	12	67.9	straight	normal
24	31	230	105	103	2	86.0	straight	Normal
25	21	190	116	104	12	81.1	straight	normal
26	31	244	77	74	3	89.4	straight	normal
27	21	300	142	133	9	98.3	straight	normal

cases this can be explained on the basis of fewer plants being produced on such plots.

Laboratory

The effect of the different chemicals on capillary rise of moisture in the soil is shown in Table VIII. The soil is deflocculated by the sodium compounds, but it is not so marked in this experiment. The sodium ions in the soil solution and those on the base exchange complex tend to reach an equilibrium. As the water rose through the soil there was a tendency for the sodium ions in the soil solution to move downward and to be carried away by the running water.

These differences would have been more noticeable had the soil tubes been higher.

Preliminary work on percolation showed a tendency for the deflocculated particles in soil treated with sodium compound to be carried downward until they formed an impervious layer through which water would not penetrate.

The complete results of the work in the bacteriology laboratory will not be given here as that work is a paper in itself. Any reader who wishes to know more about this phase of the work can secure that information from Professor P. L. Gainey who directed this phase of the work.

TABLE VIII. RISE OF CAPILLARY MOISTURE IN INCHES

Soil Treated at Rate of 2000 Pounds per Acre

Experiment Started at 5:00 a.m.

Chemical Used	5:10	5:40	6:00	12 M.
Carbon disulphide	4	7	7	7
Carbon tetrachloride	3.5	6.5	7	7
Paradichlorobenzine	3	5.5	7	7
Naphthalene	3.25	6.5	7	7
Sulphur	4	6	7	7
Copper carbonate	3.5	5.5	7	7
Paris green	3.75	7	7	7
White arsenate	4	6.5	7	7
Calcium arsenate	3.5	6.25	7	7
Sodium arsenate	3.5	5	6	7
Sodium arsenite	3.5	5	5.75	7
Sodium chloride	3	7	7	7
Sodium fluosilicate	3	5.5	6	7
Check	3.5	5	7	7
Sodium fluoride	2.75	3.75	5	6
Sodium bicarbonate	3.75	6.5	7	7
Sodium cyanide	3.5	6	7	7
Calcium hydroxide	4.75	6.5	7	7
Calcium cyanide (G)	4.5	7	7	7
Calcium cyanide (cal)	4.5	7	7	7
Calcium fluosilicate	4.15	6	7	7
Copper sulphate	4	5.5	7	7
Tobacco dust	4	5.5	7	7
Chloropicrin	4	7	7	7
Ammonium sulphate	3.75	7	7	7
Kerosene emulsion	3.75	7	7	7
Carbon disulphide emulsion	3.75	7	7	7
Toluol	3	7	7	7
Sodium chlorate	4	6.75	7	7
Borax	3	6	6.5	7
Mercuric chloride	4	5.5	7	7
Check	3.5	5	7	7

It is sufficient to say here that white arsenic, copper sulphate, carbon disulphide, carbon disulphide emulsion, cyanogas, calcyanide, borax, sodium fluosilicate, Paris green, and sodium arsenite, when used at 2000 pounds per acre, slightly decreased the production of nitrate nitrogen. In none of the treatments, however, was the reduction sufficient to indicate that any large proportion of the nitrifying bacteria were destroyed.

Calcium arsenate, calcium fluosilicate, and toluol indicate a stimulating effect on the nitrifying bacteria when applied at the rate of 2000 pounds per acre.

In general it may be said that many substances which act quickly or are readily volatile will immediately reduce nitrification, but an increase can be expected later.

SUMMARY

1. The incorporation of any chemical insecticide into the soil will have an effect on the physical, chemical and biological properties of the soil, either detrimental or otherwise, and this effect must be given more attention by workers in the field of soil entomology.

2. It calls for cooperation between the edaphologist, soil bacteriologist, soil chemist, plant physiologist, and economic entomologist.

3. Arsenic is held in the soil in such a manner that two year's leaching in the field and leaching in the laboratory did not remove the harmful effects from the soil.

4. There was no indication in this work that arsenic has a deflocculating effect on the soil.

5. The application of arsenic in any form had a very detrimental effect on the growth of crops under the climatic and soil conditions of these experiments.

6. Sodium compounds deflocculated the soil and reduced the growth of plants; the extent of the injury increased as the moisture content of the soil was reduced.

7. Results indicate that the harmful effects of borax increases as the moisture content of the soil decreases.

8. Certain insecticides such as naphthaline, calcium cyanide, and the emulsions (both carbon disulphide and kerosene) apparently lose their injurious effects within a few weeks after application.

9. Some insecticides must be applied each year while others retain their toxicity to insects for a number of years.

10. It may be advisable to use such insecticides as cyanogas, calcium cyanide, and chloropicrin which have a fertilizing possibility, and which prove toxic to insects. These should be applied a short time before planting.

11. The results of these experiments do not show if there is an accumulative effect through the repeated application of certain of these insecticides. This phase of the work should receive further study before definite recommendations are made.

Figure 1. Upper from left to right, sodium cyanide at rates of 400, 1200 and 2000 pounds per acre.

Lower from left to right, calcium cyanide (G) at rates of 400, 1200 and 2000 pounds per acre.

Check 9 at extreme right. Twelve days after application of insecticide.

Figure 2. Upper from left to right, calcium hydroxide at rates of 400, 1200 and 2000 pounds per acre.

Lower from left to right, sodium bicarbonate at rates of 400, 1200 and 2000 pounds per acre.

Check 9 at extreme right. Twelve days after application of insecticide.

Figure 1.

Figure 2.

Figure 3. Upper from left to right, calcium hydroxide at rates of 400, 1200 and 2000 pounds per acre.

Lower from left to right, sodium fluosilicate at rates of 400, 1200 and 2000 pounds per acre.

Check 9 at extreme right. Twelve days after application of insecticide.

Figure 4. Upper from left to right, sodium cyanide, calcium hydroxide and calcium cyanide at the rate of 2000 pounds per acre.

Lower from left to right, sodium fluosilicate, sodium fluoride and sodium carbonate at the rate of 2000 pounds per acre.

Check 9 at extreme right. Twelve days after application of insecticide.

Figure 3'

Figure 4.

Figure 5. Upper from left to right, calcium hydroxide at rates of 400, 1200 and 2000 pounds per acre.

Lower from left to right, sodium fluoride at rates of 400, 1200 and 2000 pounds per acre.

Check 6 at extreme right. Twelve days after application of insecticide.

Figure 5.

Figure 6. Calcium arsenate at rates of:

9^1 - 400 pounds per acre.
9^3 - 1200 pounds per acre.
9^5 - 2000 pounds per acre.
C^1 - Check.
C^2 - Check.

Taken 28 days after application of insecticide. Plants 18 days old. Notice decreasing growth with increasing application.

Figure 7. Sodium fluosilicate at rates of:

14^1 - 400 pounds per acre.
14^3 - 1200 pounds per acre.
14^5 - 2000 pounds per acre.
C^1 - Check.
C^2 - Check.

Taken 28 days after application of insecticide. Plants 18 days old.

Figure 6.

Figure 7.

Figure 8. Naphthaline at rates of:

4^1 - 400 pounds per acre.
4^3 - 1200 pounds per acre.
4^5 - 2000 pounds per acre.

Paris green at rates of:

7^1 - 400 pounds per acre.
7^3 - 1200 pounds per acre.
7^5 - 2000 pounds per acre.
C^2 - Check.

Taken 28 days after application of insecticides. Plants 18 days old. Notice decreasing growth with increase of application.

Figure 9. White arsenic at rates of:

8^1 - 400 pounds per acre.
8^3 - 1200 pounds per acre.
8^5 - 2000 pounds per acre.
C^1 - Check.
C^2 - Check.

Taken 28 days after application of insecticide. Plants 18 days old. Notice decreasing growth with increase of application.

Figure 8.

Figure 9.

Figure 10. Sodium chlorate at rates of:

29^1 - 400 pounds per acre.
29^3 - 1200 pounds per acre.
29^5 - 2000 pounds per acre.
C^1 - Check.
C^2 - Check.

Taken 28 days after application of insecticide. Plants 18 days old. Notice decrease of growth in heavier applications.

Figure 11. Borax at rates of:

30^1_3 - 400 pounds per acre.
30^3 - 1200 pounds per acre.
30^5 - 2000 pounds per acre.
C^1_2 - Check.
C^2 - Check.

Taken 28 days after application of insecticide. Plants 18 days old. Notice only one plant growing in lightest application.

Figure 10.

Figure 11.

Figure 12. Mercuric chloride at rates of:

31^1 - 400 pounds per acre.
31^3 - 1200 pounds per acre.
31^5 - 2000 pounds per acre.
C^1 - Check.
C^2 - Check.

Taken 28 days after application of insecticide. Plants 18 days old. No growth in two h heavier applications.

Figure 13. The arrangement of soil pots in the greenhouse work of 1928-1929. First row running full length of concrete bench was treated at the rate of 400 pounds per acre; each pot treated with a different insecticide. Second row treated at the rate of 1200 pounds per acre. Third row treated at the rate of 2000 pounds per acre. Fourth row, at extreme right, treated at the rate of 2000 pounds per acre. This row did not have corn planted in it. Rate of evaporation and soil penetration tests were run on this series. Four of the checks are at extreme left.

Figure 12.

Figure 13.

Figure 14. Naphthaline at rates of:

4^1 - 400 pounds per acre.
4^3 - 1200 pounds per acre.
4^5 - 2000 pounds per acre.
C^2 - Check.

Taken 140 days after application of insecticide. Plants 14 days old. Very little difference in rate of growth. Toxic effect shown in Figure 8 disappeared after first crop.

Figure 15. Calcium arsenate at rates of:

9^1 - 400 pounds per acre.
9^3 - 1200 pounds per acre.
9^5 - 2000 pounds per acre.
C^2 - Check.

Taken 140 days after application of insecticide. Plants 14 days old. Notice decrease in rate of growth with increase in application. This is typical of all arsenical compounds.

Figure 14.

Figure 15.

Figure 16. Sodium fluosilicate at rates of:

14_1 - 400 pounds per acre.
14_3 - 1200 pounds per acre.
14_5 - 2000 pounds per acre.
C^2 - Check.

Taken 140 days after application of insecticide. Plants 14 days old. Notice lack of germination in 1200-pound application. This is common in soil treated with sodium compounds.

Figure 17. Copper sulphate at rates of:

22_1 - 400 pounds per acre.
22_3 - 1200 pounds per acre.
22_5 - 2000 pounds per acre.
C^2 - Check.

Taken 140 days after application of insecticide. Plants 14 days old. Notice decrease in rate of growth with increase of rate of application. This is typical of soil treated with copper compounds.

Figure 16.

Figure 17.

Figure 18. Chloropicrin at rates of:

24^1_3 - 400 pounds per acre.
24^3_5 - 1200 pounds per acre.
24^5 - 2000 pounds per acre.
C^2 - Check.

Taken 140 days after application of insecticide. Plants 14 days old. Notice very little difference in rate of growth between the treated pots and the check. This chemical acts similar to ammonium sulphate.

Figure 19. Borax at the rates of:

30^1_3 - 400 pounds per acre.
30^3_5 - 1200 pounds per acre.
30^5 - 2000 pounds per acre.
C^2 - Check.

Taken 140 days after application of insecticide. Plants 14 days old. Notice marked decrease in rate of growth with increase of rate of application. These pots were kept at a moisture content of about 30 per cent. Had the moisture content been lower the 400-pound application would look similar to the 2000-pound application.

Figure 18.

Figure 19.

Figure 20. Plants from sodium fluosilicate series. Reading from left to right, check; plant from soil with 400-pound treatment; plant from soil with 2000-pound treatment. Plants failed to germinate in the 1200-pound treatment. These straight heavy roots with few root hairs are typical of plants grown in sodium treated soil.

Figure 21. Plants from borax series. Reading from left to right, check; plant from soil with 400-pound treatment; plant from soil with 1200-pound treatment; plant from soil with 2000-pound treatment. The long root on a plant in the 400-pound application grew down a crack in the soil near the outside of the pot. Notice lack of root growth in practically all of this treatment.

Figure 20.

Figure 21.

Figure 22. Plants from calcium arsenate series. Reading from left to right, check; plant from soil with 400-pound treatment; plant from soil with 1200-pound treatment; plant from soil with 2000-pound treatment. Notice smaller root growth as rate of application increases.

Figure 23. Plants from chloropicrin series. Reading from left to right, check; plant from soil with 400-pound treatment; plant from soil with 1200-pound treatment; plant from soil with 2000-pound treatment. Notice little difference in root development between the treated and check plants.

Figure 22.

Figure 23.

Figure 24. Plants from calcium cyanide (G) series. Reading from left to right, check; plant from 400-pound treatment; plant from 1200-pound treatment; plant from 2000-pound treatment. Notice the greater amount of root growth in the treated pots than in the check.

Figure 25. Plants from lead arsenate series. Reading from left to right, check; plant from 400-pound treatment; plant from 1200-pound treatment; plant from 2000-pound treatment. Notice decrease in root development with increase of application. This is typical of plants grown in soil treated with arsenate.

Figure 24.

Figure 25.

Figure 26. Calcium arsenate - Application of 1000 pounds per acre. Fifteen months after treatment.

Figure 27. Paradichlorobenzine - Application of 1000 pounds per acre. Fifteen months after treatment.

Figure 28. Sodium cyanide - Application of 1000 pounds per acre. Fifteen months after treatment.

Figure 29. Tobacco Dust - Application of 1000 pounds per acre. Fifteen months after treatment.

Figure 26.

Figure 27.

Figure 28.

Figure 29.

Figure 30. Reading from left to right, check; white arsenic, applications of 400, 800, 1200, 1600 and 2000 pounds per acre. Eighteen months after application.

Figure 31. Reading from left to right, calcium arsenate applications of 400, 1200 and 2000 pounds per acre; check in center; lead arsenate applications of 400, 1200 and 2000 pounds per acre. Seven months after treatment. This was preliminary work done in the early part of 1928.

Figure 30.

Figure 31.

Figure 32. Arrangement of plots in the field. Field house in background.

Figure 33. Instrument for measuring pressure required to penetrate treated soil a given distance. Pressure is measured in foot pounds. The central rod is driven through the sheath (held in the right hand) by the weight (held in the left hand) being dropped to the collar welded on the central rod.

Figure 32

Figure 33.

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